MEDICAL GUIDANCE NOTE

TITLE:	**THE MEDICAL MANAGEMENT OF THE ENTRAPPED PATIENT WITH CRUSH SYNDROME**
REVISED:	**October 2019**

INTRODUCTION

The following clinical guideline has been developed by the International Search and Rescue Advisory Group (INSARAG), Medical Working Group (MWG), which consists of medical professionals actively involved in the Urban Search and Rescue (USAR) medicine. The MWG is comprised of representatives from multiple countries and organisations drawn from the three INSARAG regional groups.

This clinical guideline outlines a recommended approach to the management of crush syndrome in the *austere environment of collapse structure response*. While this is not intended to be a prescriptive medical protocol, USAR teams are encouraged to develop or review their own crush syndrome protocols within the context of this document.

There is a lack of evidence-based research into prehospital treatment of crush syndrome in the collapsed structure environment. This document is to be considered as a consensus statement by members of the MWG based on current medical literature, expertise, and experience.

In addition, it must be understood that these guidelines have been developed for application in a specific environment that may be complicated by factors such as:

- Hazards to rescuers and patients e.g., secondary collapse; hazardous material;
- Limited access to entrapped patient;
- Limitations of medical and rescue equipment within the confined space;[1]
- Prolonged extrication and evacuation of patient;
- Delayed access to definitive care.

DEFINITIONS & BACKGROUND

Crush Injury: Entrapment of parts of the body due to a compressive force that results in physical injury and or ischaemic injury to the muscle of the affected area. If significant muscle mass is involved, it can lead to *crush syndrome* following release of the compressive force.

[1] Advances in technology are increasingly permitting enhanced evaluation and diagnostics in the field. Practitioners are encouraged to apply these technologies as they become available and proven for use in the field.

Crush Syndrome: A potentially life-threatening, systemic condition that can occur after release of a compressive force that has been applied to a muscle mass. Factors contributing to the development crush syndrome include:

- Degree of compressive force;
- Amount of muscle mass involved;
- Duration of compression.

The onset of crush syndrome occurs following reperfusion of injured muscle when the compressive force is released. This may result in acute and or delayed onset clinical sequelae.

Acute onset pathophysiological concerns are:

- Hypovolaemia;
- Electrolyte imbalances including hyperkalaemia, which may result in acute cardiac dysrhythmias;
- Metabolic acidosis;
- Acute kidney injury (AKI).

Delayed onset pathophysiological concerns include:

- Renal failure;
- Adult Respiratory Distress Syndrome (ARDS);
- Coagulopathy;
- Severe sepsis.

Clinical evidence dictates immediate medical care be initiated as soon as patients are accessed in the rubble. Delayed medical care and or inappropriate rescue management *may result in rapid clinical deterioration and death of the patient* (e.g., uncontrolled rapid removal of the compressive force before initiation of medical care).

Other relevant USAR components (search, rescue, engineering) must be familiar with this requirement and its proper execution requires close cooperation and coordination between team disciplines.

CLINICAL PRESENTATION

All patients entrapped within a structural collapse environment should be considered to have crush syndrome until proven otherwise. Rescuers and medical personnel should maintain a high index of suspicion of the potential for crush syndrome taking into account the following:

- There may be no obvious physical signs of crush syndrome and the patient's vital signs may initially be normal;

- There may be difficulty in visually inspecting body parts that are crushed due to position of the patient;
- Patient inspection may be complicated by dust and debris covering affected body parts;
- Physical signs of the affected area, when apparent, may include:
    - Discoloured, mottled, blistered or pale skin;
    - Damaged tissue;
    - Oedema;
    - Reddish-brown urine;
    - Absent or diminished distal pulses in affected limbs;
    - General signs of shock.

Examples of skin discolouration

Example of reddish-brown urine

- Symptoms:
    - Dysaesthesia (e.g.; paraesthesia; hypoaesthesia; hyperaesthesia);
    - Anaesthesia;

- Pain:
  - Presence and level of pain may not reflect the level of severity of injury;
  - May be exacerbated on movement/release;
- Paralysis or paresis of the affected limbs;
- Decreased urine output.

Important Note: Crush syndrome may be incorrectly diagnosed as a spinal cord injury. This is an important differential diagnosis to make as the treatment regimes differ significantly. If in any doubt, treat as crush syndrome while protecting the spine until spinal injury can be excluded.

MANAGEMENT STRATEGY

For the general approach to patient treatment in the confined space environment see the MWG guidance note, *Provision of Medical Care in an Austere Environment Specifically in a Confined Space,* which describes overall patient approach, assessment, monitoring, and treatment (available at https://www.insarag.org). If relevant, refer to MWG guidance note *Amputations and Dismemberment* also available at the same website.

General Management

It is imperative that patient assessment and treatment begin as soon as the patient is accessed.

In the collapsed structure environment, rescuers must assume that victims will have some level of crush injury predisposing them to crush syndrome. Factors to consider include:

- Time of compression: Crush syndrome may develop after only one hour of compression depending on the muscle mass involved;
- Force: The compressive force can be from one's own body weight in a static position on a hard surface or from an external source;
- Muscle mass involved: The greater the muscle mass involved, the higher the risk for the development of crush syndrome (e.g. proximal limb, gluteal, pectoralis).

Entrapped patients may appear stable whilst the compressive force is in place with potentially rapid deterioration when it is removed.

The removal of the compressive force is one of the most critical phases of the extrication. Therefore, the method and timing of the removal of the compressive force should be closely *coordinated between the rescue technicians and the medical personnel*. The following factors need to be considered:

- The removal of the compressive force should not be unnecessarily delayed as the severity of crush syndrome is affected by the duration of compression;

- The method and means of extrication and egress should be prepared prior to the removal of the compressive force;
- The required medical treatment and extrication equipment should be immediately available once the compressive force has been removed;
- The method of transport should be pre-established (this may include unconventional means such as use of a private vehicle with USAR medical team accompanying the patient);
- An appropriate receiving healthcare facility and route should be pre-identified. Ideally the receiving facility should have the ability to provide dialysis;
- When possible, pre-notification of the receiving facility should occur.

Fluid Management in Crush Syndrome

Important Considerations:

- Currently there is no strong scientific evidence to support any single definitive fluid regime for the treatment of crush syndrome in the collapsed structure environment. However, fluid administration remains the cornerstone of therapy;
- In the USAR environment, fluid loading of the patient is recommended as one of the most important actions **prior** to release of the compressive force;
- The USAR environment may preclude an ability to definitively monitor haemodynamic, electrolyte and metabolic status of the patient. However, some of the following may be possible and have been successfully used in the collapsed structure environment:
    - Cardiac monitoring for signs of hyperkalemia;
    - Portable sonography for evaluation of hydration status and perfusion;
    - Point of care (POC) testing for metabolic derangements.
- Hyperkalemia can be challenging to diagnose in the USAR environment. Indicators may include:
    - ECG changes;
    - POC testing determined hyperkalemia;
    - Hemodynamic compromise unresponsive to fluid resuscitation.

Fluid Administration

Fluid administration routes:

- Consider the following methods of vascular access:
    - Peripheral;
    - Intraosseous (IO);
    - Venous cutdown;
    - Central (least desirable, consider the risks associated with central venous access within a confined space);

- If vascular access is not possible, consider alternative routes of fluid administration recognising their limited effectiveness (poor/slow rate of absorption) and potential side effects e.g., regurgitation:
  - Orogastric;
  - Nasogastric;
  - Rectal;
  - Subcutaneous (avoid administration in crushed area);

Intravenous Fluid type: Preferably use warm, isotonic, potassium free solutions.

Fluid therapy:

- There are multiple reasons for fluid administration during the various phases of the extrication:
  - Volume replacement required to achieve haemodynamic stability;
  - Fluid loading to compensate for the sequestration of intravascular fluid into the interstitial space when the compressive force is released;
  - Maintenance of adequate renal perfusion. This may require the administration of fluid volumes that exceed volumes usually administered to a trauma patient;
  - Addressing maintenance fluid requirements.
- Volume:
  - There is no strong scientific evidence to support any particular dose of administration. However, the literature supports the use of high-volume fluids during extrication, although this should not be indiscriminate administration;
  - Many authors recommend an initial fluid administration of 1 to 1.5 litres per hour for the adult patient in the first 2 hours until hydration status can be verified. In reality, each crush patient may have varying fluid requirements and volume administered must account for other sources of on-going (dehydration) or future fluid loss (extravasation). Fluid overloading is also a risk that must be taken into consideration when calculating volume to be administered;
  - Individual fluid requirements may be difficult to assess in the collapsed structure environment, but some considerations include:
    - Time to release of the compressive force (if early release is possible, more aggressive initial fluid administration is required);
    - Preloading the patient with fluid immediately prior to release of the compressive force to reduce the risk of significant hemodynamic compromise due to sequestration. This may be achieved by the administration of rapid fluid boluses;
    - Fluid infusions require constant re-evaluation of the patient. Parameters to consider include:
      - Improved vital signs;

- Improved mental status;
- Urine production;

EVALUATING URINE PRODUCTION IN PATIENTS ENTRAPPED IN THE COLLAPSED STRUCTURE ENVIRONMENT
Monitoring haemodynamic status using urinary output can be difficult to assess in the USAR environment, however: o Encourage patient to urinate into a container if possible and if they feel the need; o Make note of times patient urinates; o Observe the colour and estimate the volume, if possible; o It is not generally advisable to attempt bladder catheterization within a confined space. As an alternative consider the use of a condom catheter in a male patient. o A single collection of urine is not always a reliable confirmation of ongoing renal function. o Similarly, the lack of urine production in the first few hours is not a reliable indicator of anuria.

- Skin turgor;
- Production of tears;
- Moist mucous membranes;
- Diagnostic technology as mentioned above (e.g. field sonography in the rubble pile).

- Special consideration should be given to the administration of fluid in the following:
    - Children and infants (e.g. initial bolus 15-20ml/kg);
    - Those with lower muscle mass (potentially reduce fluid volumes):
        - Elderly;
        - Chronically malnourished;
    - Patients with known co-morbid conditions e.g.; heart failure (potentially reduce fluid volumes);
    - The principles of damage control resuscitation (e.g.; permissive hypotension) may not necessarily apply.
- Other General recommendations:
    - Insulate fluids in cold environments;
    - Use pressure infuser devices in conjunction with rate control devices to aid with fluid administration. The confined space environment often precludes being able to place the intravenous fluid container above the level of the patient's heart thereby preventing fluid flow or resulting in blood backflow up the administration set. Do not delay fluid administration waiting for equipment as manually squeezing the bag is an effective interim measure;
    - Ensure vascular access sites are adequately secured;
    - Consider the use of IV extension tubing to facilitate easier administration of fluid and medication;

- Use two sites of intravenous access, if possible;
- Adhere to sterile procedures as far as possible;
- Maintain a record of the type and volume of fluid administered.

Medications

Important Considerations:

- Acute renal failure is a potential consequence of crush syndrome, therefore, medications with known nephrotoxic effects must be avoided if at all possible, e.g.; non-steroidal anti-inflammatory drugs (NSAIDs);
- Patients presenting with possible acute renal failure may accumulate excessive doses of an administered drug due to inability of urinary excretion leading to toxicity.

Recommendations

- The medical literature and USAR experience support the early administration of the following medications:
    - Sodium Bicarbonate 8.4% (e.g.; 50 ml IV in an average adult patient) prior to removal of the compressive force. Although there is no strong scientific evidence to support additional bolus doses, this may be considered in a prolonged extrication. Subsequent slow intravenous infusion may assist with alkaline diuresis which is thought to aid renal protection;
    - Analgesia: Appropriate and adequate analgesia is not only important for patient comfort; it may assist with patient extrication. Selection of analgesic may be influenced by the scope of practice, duration of action, renal elimination, effect on the haemodynamic profile and need for airway support;
    - Antibiotics: preferably broad spectrum (including anaerobes) intravenous or intramuscular in non-damaged tissue; avoid nephrotoxic antibiotics (e.g. aminoglycosides).
- If hyperkalemia is suspected, the following are well established treatments for this condition:
    - Sodium Bicarbonate 8.4%;
    - Calcium 10%;
    - Beta-2 agonist;
    - Intravenous dextrose and insulin;
    - Polystyrene sulfonate or resonium calcium (when practical and if prolonged transfer to tertiary care is expected).

Notes:

- Mannitol 20%: May be considered once ongoing urinary production and output has been verified. Note: Mannitol is contraindicated in anuric states;
- Although the use of allopurinol has been described in patients with non-crush syndrome rhabdomyolysis, its use in crush syndrome is not described;

- Acetazolamide has also been recommended for treatment, however its use in the confined space environment is not well studied;
- Furosemide can have unfavorable heamodynamic side effects and causes acidification of the urine. Therefore, <u>*its use in this environment*</u> is strongly discouraged;
- Suxamethonium chloride is contra-indicated due to its exacerbation of hyperkalaemia.

Tourniquets

- There is currently no robust scientific evidence to support the routine prophylactic use of tourniquets prior to the release of the compressive force in order to prevent or delay the onset of crush syndrome;
- The use of tourniquets should be reserved for otherwise uncontrollable life-threatening haemorrhage. When tourniquets are used, they should be appropriately designed for arterial occlusion.

Post-release of the compressive force

- During and immediately following removal of the compressive force, reassess the patient's clinical condition as it may rapidly deteriorate;
- Reassess vascular access integrity;
- Coordinate the extrication and evacuation with the rescue team as per the pre-planned strategy;
- Continuously monitor the ECG for signs of acute hyperkalaemia as soon as practical;
- Continuously monitor the patient's hemodynamic status.

Compartment Syndrome

Following the release of the compressive force, patients may develop a compartment syndrome. Current medical literature and experience discourages the use of fasciotomies <u>*in the USAR environment*</u> due to the high rates of sepsis and bleeding complications, which may be life-threatening.

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